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Biological & Medical Serials

Memoirs of the Department of Agriculture in India.

THE COMPOSITION OF INDIAN RAIN AND DEW.

BY

J. WALTER LEATHER, PH.D., F.I.C., F.C.S.,

Agricultural Chemist to the Government of India.

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CHEMICAL SERIES

VOL. I

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CONTENTS.

VOL. I.

		Page.
No. 1.	Leather, J. W. The Composition of Indian Rain and Dew .	1
No. 2.	Leather, J. W. The Composition of the Oil-Seeds of India ...	13
No. 3.	Leather, J. W. The Pot-Culture House at the Agricultural Research Institute, Pusa. (With one text-figure, eight plates and one chart)	39
No. 4.	Leather, J. W. Experiments on the Availability of Phosphates and Potash in Soils. (With six charts)	45
No. 5.	Arnott, M. H., and Leather, J. W. The Construction of Drain Gauges at Pusa. (With twenty plates)	59
No. 6.	Leather, J. W. The Loss of Water from Soil during Dry Weather. (With one text-figure and seven plates) ...	79
No. 7.	Leather, J. W., and Jatindra Nath Sen. The System Water, Calcium Carbonate, Carbonic Acid. (With seven plates)	117
No. 8.	Leather, J. W. Water Requirements of Crops in India. (With fifteen plates and twenty charts)	133
No. 9.	Annett, H. E. The Nature of the Colour of Black Cotton Soil	185
No. 10.	Leather, J. W. Water Requirements of Crops in India, II. (With two plates and numerous charts)	205

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PART I.

NITROGEN IN THE RAINFALL.

THE amount of ammonia and nitric or nitrous acid, which has been found in the annual rainfall by observers in different parts of the world, has varied within wide limits. One of the most complete statements of the existing knowledge on the subject is found in a recent paper by N. H. J. Miller,[1] from which the following instances may be quoted illustrating extreme quantities. Gray, New Zealand, found ·50lbs. of nitrogen as ammonia per acre per annum in 1884-8, and Marcano and Muntz found 14·03 lb. in Venezuela, 1883-5. Welbel, at Ploty, found ·24 lb. of nitrogen as nitrate and nitrite in 1900-3, whilst Boname found 6·34 lb. in Mauritius, 1895. Most European and American chemists have met with quantities standing mid-way between these extremes. The records maintained at Rothamsted over a period of 15 years, 1889 to 1903, show mean quantities of 2·78 lb. of 'ammonia' nitrogen, and 1·19 lb. of 'nitric' nitrogen per acre per annum, the total being 3·97 lb. The variation in this record has been very small, the largest quantity registered being 4·84 lb. in 1903 and the smallest 3·30 lb. in 1890. No connection is perceptible between these variations and the season or the rainfall.

---

1 Amounts of nitrogen as ammonia and as nitric acid, and of chlorine in the rain water collected at Rothamsted by N. H. J. Miller. Journal of Agricultural Science, Vol. I, page 280.

There has been a tendency among writers on agriculture in the East to attribute to tropical rainfall much greater amounts. Atmospheric electrical discharges are specially spoken of as a cause of the formation of more nitric acid in the tropics than in the temperate zones. The evidence of different observers supports this view to only a limited degree. Subjoined are set out the *average* amounts found by different observers in Europe and in the tropics respectively, to which are added the individual data obtained at Madras, Colombo and Calcutta.

	NITROGEN. POUNDS PER ACRE.	
	As ammonia.	As nitrate & nitrite.
Mean of European observations	6·52	2·55
Mean of tropical observations	4·26	3·33
Madras : 1888-1893	Total 1·91	
Calcutta : 1891	1·79	1·20
Ceylon : 1898-9[1]	3·65	1·28

The information, then, shows firstly that the European rainfall contains more ammonia and rather less nitrate than some tropical rain ; secondly, that the relative proportion of nitric nitrogen is at times somewhat higher in the tropics. On this subject, Miller says, "The one conclusion which may safely be drawn is that tropical rain does not supply to the soil an essentially greater amount of nitrogen than the rain of temperate climates." (*Ibid*, page 287).

A record of the amount of these nitrogen compounds was kept recently for twelve months in the rain at Dehra Dun, situated in N. Lat. 30° E. Long. 78° and at Cawnpore, N. Lat. 27° E. Long. 80°, and this record is of interest as additional evidence on the subject.

Samples.—Specimens of the rain water were stored whenever any fell, and once every fortnight (or less) these specimens were mixed together in proportion to the individual falls to which they belonged.

Analytical methods employed.—For the estimation of the *ammonia* 500 cc. were distilled after the addition of 1 drop of concentrated potassium hydrate solution, and the distillate nesslerised. The nessler solution was sufficiently delicate to indicate ·005

[1] M. K. Pamber, Report on Ceylon Tea Soils, Colombo, 1900.

m.gr. of NH_3 *readily.* The *nitrate and nitrite* was determined by Warington's modification of Schloesing's method.

The accompanying statement contains the record.

Dehra Dun.

1904.	Rainfall inches.	NITROGEN.				
		Parts per million.		Pounds per acre.		
		As Ammonia.	As Nitrate and Nitrite.	As Ammonia.	As Nitrate and Nitrite.	Total.
January 15th ...	·54	·49	·129	·059	·016	·075
January 18th ...	·98	16	·044	·034	·010	·044
February 4th ...	·06	·82	·728	·011	·010	·021
March 3-4th ...	1·66	·13	·063	·049	·024	·073
March 7th ...	·38	·33	·127	·029	·011	·040
March 8th ...	·07	·56	·169	·009	·002	·011
March 9th ...	·96	·22	·106	·049	·023	·072
April 8-9th ...	·10	·57	·039	·013	·001	·014
April 14th ...	·10	·11	·890	·003	·020	·023
May 8-15th ..	1·20	·45	·010	·123	·003	·126
May 23-25th ...	·82	·58	·300	·109	·055	·164
May 31st—June 12th ...	·42	·21	·108	·020	·010	·030
June 20-30th ...	3·35	·20	·147	·152	·112	·264
July 2-13th ...	13·66	·13	·050	·408	·155	·563
July 14-27th ...	16·11	·11	·080	·402	·293	·695
July 28th—Aug. 13th ...	19·09	·05	·060	·221	·226	·447
August 14-30th ...	18·04	·04	·050	·164	·206	·370
September 1st-17th ...	5·24	·04	·041	047	·048	·095
Sept. 18th—Oct. 12th ...	·76	·03	...	·005	...	·005
November 12-16th ...	·92	·30	·210	·062	·044	·106
Nov. 17th—Dec. 31st ..	2·02	·15	·210	·068	·099	·167
Total ..	86·48	·104	·070	2·037	1·368	3·405

Cawnpore.

1904-05.	Rainfall inches.	NITROGEN.				
		PARTS PER MILLION.		POUNDS PER ACRE.		
		As Ammonia.	As nitrate and nitrite.	As ammonia.	As nitrate and nitrite.	Total.
May 1-15th ...	·19	·446	·031	·019	·001	·020
May 16-31st ...	·23	·461	·103	·024	·005	·029
June 1-15th ...	·26	·148	·050	·009	·003	·012
June 16-30th ...	3·77	·247	·067	·211	·058	·269
July 1-15th ...	5·67	·230	·080	·296	·104	·400
July 16-31st ...	11·13	·240	·082	·606	·208	·814
August 1-15th ..	6·74	·200	·059	·306	·091	·397
August 16-31st ...	4·79	·210	·120	·228	·130	·358
September 1-15th ...	10·77	·080	*Nil*	·191	*Nil*	·191
September 16-30th ...	2·50	·080		·045	*Nil*	·045
October 1-15th ...	*Nil*	...	... ..	...	.....	...
October 16-31st ...	·03	·550	·470	·004	·003	·007
November 1-15th ...	·41	·910	·384	·084	·035	·119
November 16-30th ...	*Nil*	...	.....	...	... ..	...
December 1-15th ...	·30	1·020	·220	·069	·015	·084
December 16-31st ...	·68	·044	·210	·007	·033	·040
January 1-15th ...	·26	1·240	1·100	·073	·006	·079
January 16-31st ...	*Nil*	..	.....	...	.....	...
February 1-15th ...	·11	1·040	·839	·026	·021	·047
February 16-28th ...	1·36	·830	·178	·256	·055	·311
March 1-15th ...	·16	·780	.. ...	·028	... ..	·028
March 16-31st ...	·045	probably	contaminat	ed	.....	...
April 1-30th ...	·055	not	analysed	...	.....	...
TOTAL ..	49·36	·221	·068	2·482	·768	3·250

Totals for the twelve months' periods.

	Rainfall inches.	NITROGEN.					
		Parts per million.		Pounds per acre.			Ratio "NH_3" N to "HNO_3" N.
		As ammonia.	As nitrate and nitrite.	As ammonia.	As nitrate and nitrite.	Total.	
Dehra Dun	86·48	·104	·070	2·037	1·368	3·405	1 : ·67
Cawnpore	49·36	·221	·068	2·482	·768	3·250	1 : ·31
Compare Rothamsted ...	27·25	·440	·183	2·712	1·128	3·840	1 : ·42

In addition to the total quantities observed at the two Indian stations, the mean figures of Rothamsted are quoted for comparison.

The following conclusions may be drawn from this record :—

(*a*) The total quantity of nitrogen carried by the rain from the atmosphere to the soil at Dehra Dun and Cawnpore is approximately equal to that in the rain at Rothamsted. The largest amount found at the latter station during 15 years was 4·429 lb., and the smallest 3·427 lb. per acre.

(*b*) The ratio of 'ammonia' nitrogen to 'nitric' nitrogen at Rothamsted has been 2·712 : 1·128=1 : ·417. So that the *relative* amount of nitric acid in the rain at Dehra Dun was considerably greater than at Rothamsted, whereas at Cawnpore it was somewhat less.

(*c*) A comparison of the actual amounts, however, shows that the rain at the two Indian stations contained less ammonia than at the English one ; of nitric acid the Dehra Dun rain contained somewhat more, the Cawnpore rain a good deal less than at Rothamsted.

(*d*) Dehra Dun lies at the foot of the Himalayas and its elevation is about 2,000 ft. above sea-level at the point where the samples were collected. The rainfall is frequently accompanied by heavy thunderstorms, these electrical phenomena being in excess of what is usual in the Indo-Gangetic alluvial area, in which Cawnpore is situated. As the record shows, the amount of nitric acid in the

Dehra rain exceeded considerably that in the Cawnpore rain, and the one year's observations thus add something to the theory that the amount of nitric acid is increased by thunderstorms. But there is no evidence that this factor affects in any material degree the *total* amount of combined nitrogen in the rain. It is true that neither Dehra nor Cawnpore is situated within the tropics, but they are both so nearly so, that if any marked increase in the amount of combined nitrogen was usual in tropical rain, some definite indication of the fact should be present in the rain-waters we are considering.

The data may also be examined for differences in the amount of combined nitrogen in rainfalls of different magnitude. If these substances are washed out of the atmosphere by the falling rain and not obtained principally from that stratum in which the rain is formed, it may be presumed that, on the basis of the law of mass action, the first rain will dissolve out more than the later rain, because the latter will meet with less solute on its passage through the air. The first rain should, therefore, contain more ammonia and nitrate per unit volume. But whether it would contain a greater total amount would depend on the quantity of this "first" part of the fall. It would have been better for this particular purpose if the earlier portion of certain falls had been measured and analysed separately from the later part. This was not done principally because of pressure of other work. However, the data nevertheless provide indirect information on the subject. If the composition of small and large precipitations respectively, received after equal periods of dry weather, are compared, then, assuming that equal amounts of ammonia and nitrate were present in the air, the *concentration* of nitrogen compounds in the lesser fall should be greater than in the larger one ; but if the lesser fall is only very small, the *total quantity* of combined nitrogen in it will be less than in the larger one. The data are accordingly arranged below in groups, each group including rainfalls which were preceded by equal intervals of dry weather. Thus we have two falls after less than one dry day, two after three dry days, two after seventeen and nineteen dry days, and two after four weeks of dry weather.

Date.	Interval between falls.	Rainfall inches.	NITROGEN.				
			Parts per million.		Pounds per acre.		
			As ammonia.	As nitrate or nitrite.	As ammonia.	As. nitrate or nitrite.	Total.
March 8th ...	1 day	·07	·56	·17	·009	·002	·011
March 9th ...	1 ,,	·96	·22	·11	·049	·023	·072
January 18th...	3 days	·98	·16	·04	·034	·010	·044
March 7th ..	3 ,,	·38	·33	·13	·029	·011	·040
February 4th...	17 days	·06	·82	·73	·011	·010	·021
January 15th .	19 ,,	·54	·49	·13	·059	·016	·075
March 3-4th .	4 weeks	1·66	·13	·06	·049	·024	·073
April 8-9th ...	4 ,,	·10	·57	·04	·013	·001	·014

Examination of the data in this manner reveals very considerable regularity. The fall of March 8th was a very small one, and although rain had fallen on the previous day, this smaller fall contained, per million parts, more ammonia and nitrate than its predecessor. On the following day the fall was heavy (·96″). This contained less nitrogen per million parts. But comparing the total amounts of nitrogen brought into the soil by these two falls, it is evident that the heavier fall carried a much greater quantity with it.

The next group includes the falls of January 18th and March 7th. Both these were received after three dry days, but the former and greater fall contained less ammonia and "nitric" nitrogen per million parts than the smaller fall. In comparing the *total* nitrogen in these two precipitations, it is necessary to note that the lesser was not a very small quantity—·38″—, and might be quite sufficient to wash out what ammonia was in the air, if indeed this constituent is mainly obtained in this manner. In that case the *total* nitrogen in these two rainfalls would not exhibit the great difference which is noticeable between the first pair, and as a matter of fact the greater fall contained ·044 lb. per acre and the latter ·040 lb.

The third group includes one fall of ·06″ after seventeen days of dry weather, and one of ·54″ after nineteen dry days. The magnitudes of precipitation are here similar to the first group, and the relations between the concentration on the one hand and total quantity

on the other, are also the same ; the lesser fall possessed the higher concentration of nitrogen compounds, but a much less total weight. Finally, the fourth group is similar in characteristics to the first and third.

In drawing conclusions from the data here discussed, their limited nature has to be remembered. Subject to this reservation it may be said that the evidence points in one direction, and shows that among rainfalls, *succeeding equal periods of dry weather*, the lesser precipitation will possess a greater concentration of nitrogen compounds than the greater. As to the total quantity of these compounds, the lesser fall *may* contain as much as the greater, provided it is not too small, but that falls of ·1″ and less do not contain as much as heavier falls. It is important to note the italicised condition. If these rainfalls are merely arranged in order of the magnitude of the rainfall, without reference to the preceding dry weather, no simple generalisations are possible.

The amount of combined nitrogen in rainfalls of different magnitude and after different periods of dry weather was referred to by Lawes and Gilbert in their second paper[1] on the composition of rain water. They say (page 315) " one condition which very largely determines the amount of ammonia present is undoubtedly the quantity of the rainfall ; with increasing quantities of rain the proportion of ammonia always tends to diminish. This is best shown in Table II in which the whole of the daily rainfalls are grouped according to quantity."

PART II.

NITROGEN IN THE DEW.

The rain-gauge at Cawnpore consists of an inverted pyramid of sheet iron, having an area of 1/1,000 part of an acre. It is, in fact, similar to that employed at Rothamsted, excepting that it stands above ground and is of different material. The quantity of dew,

1 " New determinations of ammonia, chlorine and sulphuric acid in the rain water collected at Rothamsted." By J. B. Lawes, J. H. Gilbert and R. Warington. Journal of the Royal Agricultural Society, England, XIX, ii series, 1883, page 313.

which is very heavy at certain periods of the year in India, was collected on this gauge, and was measured during several months of the "cold weather" of 1904 to 1905; a record of its composition was also kept. There is a danger when collecting such small precipitations, lest any accidental impurities fall on the gauge, and one of the samples contained so much more ammonia than the remainder, that it was discarded as probably contaminated. The record is contained in the subjoined statement.

Period.	Dew in inches.	Nitrogen.				
		Parts per million.		Pounds per acre.		Total.
		As ammonia.	As nitrate or nitrite.	As ammonia.	As nitrate or nitrite.	
September 1904, 16—30 ...	·011	·85	·51	·002	·001	·003
October ,, 1—15 ...	·011	...	·91	...	·002	·002
Do. ,, 16—31 ...	·011	1·6	2·23	·004	·006	·010
November ,, 1—15 ...	·016	1·4	1·49	·005	·005	·010
Do. ,, 16—30 ...	·027	... discarded as unreliable				...
December ,, 1—15 ...	·015	1·7	1·09	·006	·004	·010
Do. ,, 16—31 ...	·019	1·2	·72	·005	·003	·008
January 1905, 1—15 ...	·020	2·2	2·32	·010	·011	·021
Do. ,, 16—31 ..	·015	2·6	1·83	·009	·006	·015
February ,, 1—28 ...	·017	2·65	4·12	·010	·015	·025
March ,, 1—15 ...	·008	2·5	1·90	·004	·003	·007
Total	·170	...	...	·055	·056	·111

The available information regarding the quantity and composition of dew is but limited. It was measured at Montpellier, 1893-95,[1] by Hondaille, who determined the deposit which collected on a glass plate of 25 sq. cm. area. Dew was registered in every month of the year, and the mean total amounted to 8·001 mm. (·32 inch) per annum. This record is about twice as great as that at Cawnpore. So far as quantity is concerned it is probable that the method adopted at Cawnpore gives a low result. The whole of the dew deposited during the night does not run off the gauge into the receiver, and what remains on the collecting surface would naturally evaporate again during the following morning. But how great the error here introduced, is not at present known. Nor in the present state of our knowledge of the actual amounts of water which evaporate daily from the soil during the several seasons of the year, is it safe

[1] Ann. Ecole. Nat. Agr., Montpellier, 9. 1895-96; Expt. Stn. Record IX, page 1032.

to express an opinion on the question whether this dew deposit *materially* affects this evaporation of water from the soil. Of the *composition* of dew even less appears to be known. Lawes and Gilbert[1] state that "most of the very small deposits represent dew"; this statement refers to the tabulated data on page 316 of their paper, but only one of these deposits is specially noticed, namely, that of September 17, 1881. It measured ·007 inch and contained 5·49 parts of ammonia per million. This appears to have been exceptional, because all the other very small deposits which were analysed, contained quantities of ammonia similar to those found in the Cawnpore dew. Another reference to the composition of dew is found in the Report of the Ploty Agricultural Experiment Station.[2] Welbel there found a mean of 5 m.gr. of ammonia per litre of dew, which is equivalent to 5 parts per million. That dew usually contains more ammonia per unit volume than rain, there seems to be no doubt, and the same applies to the nitrate. Naturally since the total deposit is so small, the total quantity of combined nitrogen thus introduced into the soil is small also. The whole of the Cawnpore deposit for the season contained only ·055 lb. of "ammonia" nitrogen and .056 lb. of " nitric " nitrogen per acre. As a source of combined nitrogen to the soil, dew deposits cannot be considered of great importance. The relatively high proportion of nitrate to ammonia in the Cawnpore dew is very marked. This relationship is fairly regular, and whilst in rain-water the "nitrate" nitrogen is nearly always less, and sometimes very much less than that occurring as ammonia, in the dew the two quantities approach each other more nearly, and in two of the specimens there was a marked excess of "nitrate " over "ammonia" nitrogen. The total quantities of the two for the season are equal, whereas in the Cawnpore rain there was three times as much "ammonia" nitrogen as "nitrate" nitrogen. This circumstance is not what one would expect. It is generally assumed that the ammonia in the atmosphere is derived (away from large towns) from decaying vegetable matter, and there should thus be an excess of

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[1] *Loc. Cit.*, page 315.

[2] Rap. An. Sta. Expt. Agron. Floty 8 (1902).

ammonia in the atmosphere nearest the earth; the nitric acid on the other hand is attributed to electrical phenomena, much of which occur in the higher atmosphere, and it might be expected that if an excess of nitric acid existed at all, it would be present in the higher strata. Arguing from these premises it might be anticipated that rain, which falls through a so much greater thickness of atmosphere than dew, would tend to contain a higher ratio of nitrate to ammonia, than dew would contain. As has been shown, the exact contrary has been met with. If a conclusion may be drawn from the composition of rain and dew, regarding the relative amounts of ammonia and nitrate or nitrite in the several strata of the atmosphere, the Cawnpore data indicate that there is relatively more nitrate in the lower strata.

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